THE MANUFACTURING METHOD OF A GALLIUM NITRIDE-BASED BLUE LIGHT EMITTING DIODE (LED) OHMIC ELECTRODES

FIELD OF THE INVENTION

This invention is related to a manufacturing method of a gallium nitride(GaN)-based blue light emitting diode (LED) ohmic electrodes and a transparent conductive layer (TCL). More specifically, it's related to a ohmic electrode and a transparent conductive layer which forms a thin composite layer upon P type gallium nitride epitaxial layer.

BACKGROUND OF THE INVENTION

US Pat. No. 5,563,422 discloses a series of manufacturing method regarding gallium nitride(GaN)-based III-V compound semiconductor devices and techniques of ohmic electrodes. Figure 1 shows the dissection of said patented invention, which is about making a gallium nitride(GaN)-based III-V compound semiconductor light emitting diode 110 with P type electrode 115 and N type electrode 114. It contains: a substrate 111; a semiconductor stacking structure above that substrate with a N type gallium nitride(N-GaN)112-based III-V compound semiconductor and a P type gallium nitride(P-GaN)113-based III-V compound semiconductor; a N type electrode(first electrode) 114 making said N type semiconductor layer in contact; a P type electrode(second electrode) 115 making said N type semiconductor layer in contact; and a pad 116 above the second electrode 115.

The second electrode 115(P type electrode) contacts to P type semiconductor 113 by forming a metallic material layer such as gold/nickel (Au/Ni) and annealing the metallic material layers.

Among said gallium nitride (GaN)-based III-V compound semiconductor devices, the second electrode 115 includes Ti/Al or Au, the second electrode 115 contains one or more metallic alloy selected from the group of gold, nickel, aluminum, platinum, tin, indium, chromium and titanium, in which gold/nickel alloy has better effects.

Even the second electrode 115 is made of gold/nickel; its resistance between electrodes is 1 kΩ, therefore, this invention offers a manufacturing method of the ohmic electrodes and the transparent conductive layer to lower serial resistance between the electrode and the gallium nitride.

SUMMARY OF THE INVENTION

The main purpose of this invention is to provide a manufacturing method of a gallium nitride(GaN)-based blue light emitting diode (LED) ohmic electrodes. Since the contacting resistance between the nickel chromium (NiCr) alloy and P type gallium nitride epitaxial layer is relatively low, a thin film alloy electrode can be grown upon the P-GaN epitaxial layer and N-GaN epitaxial layer. Moreover, better ohmic property is obtained by applying appropriate heat treatment to reduce the serial resistance between the electrodes and the P type and N type gallium nitride epitaxial layers and , in the same time, to lower the forward voltage of the light emitting diode.

Another purpose of the current invention is to offer a manufacturing method of a transparent conductive layer of a gallium nitride(GaN)-basedlight emitting diode made from NiCr alloy. By growing a layer of NiCr thin film upon P type gallium nitride epitaxial layer, and applying appropriate heat treatment on said alloy thin film to obtain better ohmic property and transparency. Since said alloy thin film is highly transparent in the wavelength range (400 - 700 nm) of visible light, its average transparency is 87.77%, which offers larger current-injecting area. The optimized transparency also improves its luminance.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 is the dissection of the structure of the known gallium nitride (GaN) blue light emitting diode.

Figure 2 is the dissection of the structure of the gallium nitride-based blue light emitting diode ohmic electrode and transparent contacting electrical conducting layer, in according to present invention.

Figure 3 is the circular transmission line model of the structure of the invented gallium nitride-based blue light emitting diode ohmic electrode and transparent contacting electrical conducting layer, in according to present invention.

Figure 4 is the circular transmission line model of the structure of the invented gallium nitride-based blue light emitting diode ohmic electrode and transparent contacting electrical conducting layer, in according to present invention.

Figure 5 is the current-voltage characteristic curves of the invented

gallium nitride-based blue light emitting diode ohmic electrode and transparent contacting electrical conducting layer after 60 seconds heat treatment under different temperature conditions, in according to present invention.

Figure 6 is the transmission plot (with various visible light wavelengths) of the alloy thin film of the invented gallium nitride-based blue light emitting diode ohmic electrode and transparent contacting electrical conducting layer after 60 seconds heat treatment under different temperature conditions.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

All the growth of semiconductor layer is carried out with metalorganic chemical vapor deposition (MOCVD) techniques and the III-V alloy semiconductor of the gallium nitride-based are nitride semiconductor of III -valance element gallium.

As shown in figure 2, common techniques of the light emitting diode displays adopt surface emitting structure, they are sapphire (Al_20_3) substrate layer 10, N type gallium nitride layer 11, N-electrode layer 12, active layer 13, P type gallium nitride layer 14, transparent electrode layer 15 and P-electrode layer 16.

This invention mainly is that there grows an alloy metallic thin film layer upon the P type gallium nitride layer 14 as shown in figure 2 to effectively disperse the injected current and take the advantage of its transparency to enhance the luminance. Examples are illustrated in the following,

EXAMPLE 1

For the sake of easier measurement of the contact resistance of P-electrode and surface resistance, the example of this invention is directly grow P type gallium nitride film layer upon sapphire C-face substrate using metalorganic chemical vapor deposition. (MOCVD)

As sown in Figure 2, a GaN epitaxial layer is grown upon the sapphire C-face substrate at about 1000 ℃. Since the magnesium (Mg) molecules haven't diffused into the crystalline lattice of the newly grown GaN crystal yet, Mg cannot be activated as an acceptor. The said gallium nitride eptixial layer is not a P type gallium nitride layer 14 but an epitaxial layer with high electrical resistance. Therefore, a process of rapid thermal annealing of 850 ℃ and 10 minutes needs to be applied to activate the epitaxial layer to be a P type gallium nitride layer 14.

Using Hall system, the sheet resistance of the P type gallium nitride layer 14 (R_s) is $1.9 \times 10^4 \Omega/\square$, the mobility ($\mu$) is 13.21 $cm^2/V\text{-}s$, concentration (p) is 1.26×10^{17} cm^{-3}.

In Figure 2, a circular transmission line model above the P type gallium nitride layer 14, as shown in Figure 4, is fabricated by photolithography, and then use Cr-Ni alloy (80% nickel and 20% chromium) as the material of vapor deposition. Under the pressure condition of 1.2×10^{-5} torr, vapor is being deposited upon P type gallium nitride layer 14 and results in a metallic thin film layer 15 as shown in Figure 3, said film thickness is controlled at around 100 angstrom. The circular transmission line model metal thin film, as shown in Figure 4, is

formed through the techniques of lifting-off.

Among the samples of the circular transmission line model as shown in Figure 4, the circular gap 22 has 9 different sizes, which are 3, 5, 7, 9, 15, 20, 25, 30 and 50 micrometer, respectively. The metallic thin film 21, 23 are the electrodes used to measure current-voltage characteristic curves. The conditions and results of the measurement are shown in Figure 5, which is also the current-voltage characteristic curve after 400~700 ℃ heat treatment for 60 seconds.

When measuring the current-voltage characteristic curve, the circular gap 22 is 50 micrometer, a better ohmic property can be obtained with above results, and circular transmission line model principle can be used to obtain contacting resistance (ρ_c) of 4.83×10^{-2} □-cm^2.

Finally, physical deposits a NiCr alloy thin film with thickness of 100 angstrom upon another P type gallium nitride which is against the metallic thin film layer 15 and P type gallium nitride layer 14, as shown in Figure 3; and then treats it with room temperature and 500~700 ℃ heat treatment for 60 seconds. Spectrophotometer measurements show the transparency of the metallic thin film at wavelength of 450 nm are 58.82%, 63.1%, 92.65%, as shown in Figure 6. Therefore, from the above example, the metallic thin film obtains better ohmic property and transparency after 700℃/60 seconds heat treatment.

Although the above example describes a transparent electrode manufacturing method of P type gallium nitride using sapphire as the substrate and physical deposits NiCr alloy thin film, said invention can be applied to the gallium nitride light emitting diode in the wavelength range

of the visible light.

The invention has been described herein with reference to certain preferred embodiments. However, as obvious variants thereon will become apparent to those skilled in the art, the invention is opt to be considered as limited thereto.